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The Efficacy of Bacillus Thuringiensis (Bt) as Biopesticide Against Fall Armyworm in Sugarcane Whorl

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Abstract: *Fall armyworm is one of the most destructive leaf feeders in sugarcane whorl. This study evaluated the efficacy of different application rates of Bacillus thuringiensis (Bt) as pest control against fall armyworm. The study used a total of ninety (90) fall armyworms collected from the Municipality of La Castellana, while Bacillus thuringiensis (Bt) was purchased from Bacolod City. Eighteen units of liter plastic containers were used to house the fall armyworms, wherein each container had five larvae. The study was laid out in Complete Randomized Design (CRD). It consisted of six (6) treatments with three (3) replications. The treatments were as follows: T1 – Control; T2– 10 grams Bt; T3 – 20 grams Bt; T4 – 30 grams Bt; T5 – 40 grams Bt; and T6-50 grams Bt. Data gathered were computed and subjected to Analysis of Variance (ANOVA) in CRD using STAR 2.0.1, and Least Significant Difference (LSD) was used to determine significant differences among treatments. Statistical analysis revealed significant differences among treatments on the mortality rate of fall armyworm as subjected to different application rates of Bt treatments, only on the 13th day of observation (F = 4.00, P = 0.0228). Results showed a complete mortality rate of fall armyworms under all application rates of Bt treatments, except only those fall armyworms under control (T1), which only got an average mortality rate of 86.67 percent, significantly inferior by 13.37 percent. Moreover, it was found that application rates of 10 grams and 40 grams (T2 and T5) of Bt treatments early obtained a complete mortality rate of fall armyworm at Day 5 compared to other treatments. On the other hand, untreated (T1) fall armyworm attained a 100 percent mortality rate on Day 16 of observation.*

Keywords: *Bacillus thuringiensis, biopesticides, control, fall armyworm, sugarcane, treatment.*

INTRODUCTION

Sugar production comes from sugarcane plants which underwent a series of processes from juice extraction to drying and packaging. Current sugarcane production in the Philippines (October-December 2021) expanded to 6.68 million metric tons, or an increase of 1.4 percent, from the 6.59 million metric tons output in 2020. Western Visayas Region continued to be the top producer of sugarcane with 5.42 million metric tons output or 81.1 percent share of the total production (Philippine Statistics Authority, 2021).

Not only to meet the demand for sugar in the market but also for the sugarcane industry to have the potential for energy have products like boiler fuel, electricity, and alcohol. In Negros, sugar and

renewable energy go hand in hand in its mills, as bagasse, a sugarcane waste, is used to power equipment. Considering the rapid escalation of energy prices due to the war crisis, investigating opportunities in producing energy products is necessary.

However, one of the significant constraints in sugarcane production is outbreaks of insects such as fall armyworm, which can inflict sizable damage that alters the production level. A fall armyworm (Spodoptera frugiperda) is a lepidopteran pest that feeds in enormous numbers on the leaves and stems of over 80 plant species, wreaking havoc on maize, rice, sorghum, sugarcane, and other vegetable crops as well as cotton (CABI, 2022). Fall armyworm is one of the most destructive leaf feeders by which the larvae travel onward after having devoured the surrounding canes in search of fresh hosts.

In December 2019, due to the rapid expansion of FAW, the FAO initiated the groundbreaking Global Action for Fall Armyworm Control. The three-year worldwide program takes bold, direct, and coordinated steps to boost global pest prevention and pest-control capacities. It adds to and strengthens the FAO's ongoing FAW efforts.

Global Action has set up a global coordinating framework to facilitate an open and collaborative debate on science-based solutions. It has also backed the formation of National Task Forces on FAW and the mobilization of funds for applied research aimed at practical and effective solutions. (FAO, 2019)

One of the measures in controlling fall armyworms is using biological control agents like Bacillus thuringiensis. Bacillus thuringiensis (Bt) is a soil-dwelling bacteria that produces a toxin that kills some herbivorous insects naturally. Since the 1920s, the Bacillus thuringiensis (Bt) toxin has already been employed as an insecticide spray and is widely utilized in organic farming. Bt is also the repository of genes that have been used to genetically edit a variety of food crops so that they may manufacture the toxin on their own to prevent numerous pest insects. The toxin is fatal to a variety of insect orders, including Lepidoptera (butterflies, moths, and skippers), Diptera (flies), and Coleoptera (beetles). However, there are numerous Bt strains available to create it more target-specific. (Mullaney, 2011)

Beron et al. (2006), were able to put together a collection of 41 isolates, some of which have a high potential for application in biological control programs against pests, including lepidopterans and coleopterans. Anticarsia gemmatalis and Spodoptera frugiperda, two major lepidopteran pests problems in Argentina, were poisonous in almost 90% of the strains.

It is worth noting that just one of these strains possessed a cry1-type gene, while another showed dual toxicity against the lepidopteran and coleopteran insects tested. The strains' genetic characterization implies that the collection contains unique Cry proteins that could be useful in biological insect pest management.

The researchers wanted to see if any organic elements might be utilized as a bio-pesticide against Fall Armyworm in crops so that the government could analyze Fall Armyworm prevention in our country. In this way, it will also provide a solution to the challenges faced by the dear farmers worldwide whose crops have been severely harmed by this pest. As a result, the researchers wanted to see if Bacillus thuringiensis (Bt) could be used as a bio-pesticide to combat the Fall Armyworm.

The study's general objective was to assess the efficacy of Bacillus thuringiensis (Bt) as pest control against Fall Armyworm (FAW) in sugarcane whorl.

This study aimed to evaluate the efficacy of different application rates of Bacillus thuringiensis (Bt) as pest control against fall armyworm (FAW) in sugarcane whorl. Specifically, it aimed to:

Determine the significant effects of different application rates of Bt treatments against fall armyworm, and determine the most effective application rate of Bt treatments used in the study. Determine the cost of expenses per Bt treatment application in the study.

Based on the previous statement of the problem, the following null hypothesis was formulated, contradictory to the problem mentioned above that there is no significant effect in using Bacillus thuringiensis as a biopesticide to the population of the FAW in sugarcane whorl.

There is no significant difference in the use of different rates of application of Bacillus thuringiensis as a biopesticide against FAW in sugarcane whorl. There is no significant difference in the study's cost of expenses per Bt treatment application.

Based on pest data for the last 100 years, the Fall armyworm (FAW), Spodoptera frugiperda (J.E. Smith), had not been known to occur in the Philippines. However, it has recently been observed as it threatens to invade the Philippines, having been reported in Taiwan and several nearby Asian nations, most notably Indonesia (Sumatra) and Thailand. FAW is said to have originated in the Americas and is extensively distributed there. Still, in 2016, it arrived and invaded Africa, and from there, it moved fast in 2018 to India and in 2019 to Sri Lanka and other Asian countries (Lit I. L., 2019).

This pest in the Philippines was found to be invasive and highly damaging to crops such as corn, rice, and sugarcane. It was only a matter of time before it reached the Philippines by the end of 2019, as reported at Piat, Cagayan in Region 2. However, at present, it was found to have infested all regions. An occurrence of FAW was reported last August 2020 in Western Visayas (Negros Occidental), wherein a 4 hectare of sugarcane was infected and treated immediately. FAW Crisis Management Team in the country has taken the following actions such as a) creation of the FAW Crisis Management Team, b) crafting of FAW National Management Strategies and Protocols, c) securing more funding support for the implementation of FAW Management, and d) expand partnership with the private sector, LGU's, academe and other stakeholders (Dr. Caranguian, 2022).

According to Navasero, et al. (2019), all FAW detections in Gonzaga and Solana, Cagayan, were from open-pollinated maize. The predominance of FAW in the mid-whorl to late whorl among the several growth stages of corn at the Gonzaga collection location could indicate that the pest prefers the early growth phases.

Similarly, FAW larvae were obtained from open-pollinated maize in mid-to-late-whorl stages in Ilocos Norte, Zamboanga del Norte and Sur, and South Cotabato (Polomolok). Second to third instar larvae were discovered on 12-day-old South Cotabato (General Santos City) plants. Oviposition occurred about 2-3 days after seedling emergence, roughly 6-7 days from egg-laying to 2nd or 3rd instar.

Fall armyworm color is pale yellow or grayish pink, with two broad dark lines running the whole body length on both sides. Severe infestation of FAW usually occurs at the onset of the rainy season after a long dry spell. During the daytime, larvae hide in the ground under cane trash or behind leaf sheaths. Defoliation of a few week-old canes can reduce yield by 14 percent. The complete life cycle of FAW lasts for 23-43 days (Akeme, Cyril Njume, et al., 2021). The presence of optimum climatic conditions for fall armyworms in many parts of Africa and Asia and an abundance of good host plants suggests that the pest can produce several generations in a single season and that the pest is likely to become endemic.

The fall armyworm (FAW), Spodoptera frugiperda (J E Smith), is an economically significant pest endemic to tropical and subtropical America that has lately infiltrated India. It was discovered in September, munching on a two-month-old sugarcane crop, variety (Co 86032), at Ghogaon village

in Sangli District (Maharashtra). Aside from sugarcane, it has also been detected in maize, sorghum, and sweet corn in several regions of Maharashtra (Chormule, Ankush, et al., 2019).

However, Montezano et al. (2018) recently found 353 host plant species from 76 plant families, based on a thorough literature study and further surveys in Brazil, from the Poaceae (106), Asteraceae (31), and Fabaceae families (31). The presence of optimum climatic conditions for fall armyworm in many parts of Africa and Asia, as well as an abundance of good host plants, suggests that the pest can produce several generations in a single season and that the pest is likely to become endemic (CABI, 2017)

Recent research indicates that the diversity of the fall armyworm that invaded Africa is more extensive than previously assumed, including a haplotype not before found in the Western Hemisphere (Nagoshi et al., 2018). According to analyses, corn and rice strains have been found in South African specimens (Jacobs et al., 2018). Fall armyworm populations in Uganda were made up of two sympatric sister species of maize-preferred and rice-preferred strains (Otim et al., 2018). Evidence from Ghana (Cock et al., 2017) and Togo (Nagoshi et al., 2018) suggests that the populations are most comparable to those found in the Caribbean region and the eastern coast of the United States.

According to Song et al. (2020), sugarcane is the principal cash crop in Guangxi, China. The fall armyworm, Spodoptera frugiperda, is an invasive pest that has been present in Guangxi since April 2019. FAW is rapidly growing throughout China, having been disseminated in over 18 provinces and municipalities. Furthermore, FAW has been demonstrated to cause significant damage to sugarcane and is a serious danger to sugarcane.

The use of synthetic pesticides for pest management is prevalent in the Philippines and elsewhere, but it has the unavoidable side effect of insect resistance development and environmental damage. Furthermore, while long-term use of chemical fertilizers can cause major soil acidification, nutritional imbalance, and damage to the rhizosphere micro-ecological environment, it also increases the activity of heavy metal ions in the soil.

Organic fertilizer application could reduce soil acidity, resulting in higher plant yields (Li et al., 2018). According to Shelton et al. (2021), farmers and farm laborers in the research claimed chemical pesticides for a variety of illnesses, including skin irritation, eye redness, muscle pains, and headaches.

As a result, in sustainable pest management programs, biopesticides provide a viable alternative to chemical pesticides (Srinivasan et al., 2019). Biopesticides include, entomopathogenic viruses, bacteria, fungi, nematodes, and secondary plant metabolites, which are gaining popularity as chemical pesticide alternatives and are an important component of many pest control programs (Nathan, 2015). Virus-based pesticides, particularly from the Baculovirus family, such as the multiple nucleopolyhedroviruses (SfMNPV), have the potential to be used in the control of fall armyworm (Haase et al., 2015).

According to Xiuqin et al. (2021), the use of biological agents as an environmentally benign means of efficiently managing and controlling the S. frugiperda infestation would be an ideal solution. Furthermore, Bacillus thuringiensis is a popular insecticide used to control fall armyworms (Jamieson (2019).

Caccia et al. (2016), found out that Bacillus thuringiensis and its toxins are commonly employed to control insects. Despite its exceptional importance, the killing mechanism of this insect pathogen is still unknown. It shows that the microbiota in the host's midgut causes fatal septicemia. The unmodified midgut microbiome allows the identification of bacterial species converting from resident symbiotic organisms to pathogens and lays the groundwork for developing novel insect

biocontrol methods based on host immune-suppressiveness as a technique to improve the effects of natural antagonists.

Furthermore, the combination oral treatment of dsRNA-Bac and a Bt-based biopesticide (XentariTM) with an artificial diet resulted in a significant increase in Bt killing activity, both on 4th and 5th instar S. littoralis, either when the two components were provided concurrently or when gene silencing was accomplished prior to Bt treatment. These findings pave the path for the creation of novel Bt spray formulations, including dead dsRNA-Bac, which synergizes Bt toxins by inhibiting the insect immune response. This technique will protect the long-term efficacy of Bt-based products and, in theory, can improve the ecological services offered by natural antagonists of insects (Caccia et al., 2020).

As a result, the researchers were curious about how they could assist farmers in reducing the FAW population. Bacillus thuringiensis was utilized to evaluate the effect of biopesticide on Fall armyworm (FAW). With the following goals in mind: Is the use of the Bacillus thuringiensis as biopesticide significantly affect the population of the FAW in sugarcane whorl? What is the most effective application rate of Bt treatments used in the study? What is the cost of expense per Bt treatment application rate in the study?

METHODOLOGY

This project assessed the different rates of application of Bacillus thuringiensis as a biopesticide against Fall Armyworm, specifically in the larval stage, wherein the most destructive stage in the crop. Bacillus thuringiensis is natural bacteria occurring in nature that, when consumed by larvae, are poisoned and eventually die. Bt has been found in nature on all continents.

It has been isolated from infected insects, dirt, granary dust, and the leaf surface of numerous plants. This bacterium is simple to culture, sporulates well in the lab, and utilizes a range of polysaccharides as carbon and energy sources (Barros et al., 2020). By the time the materials and volunteers are ready, the researcher will have managed the study's outcome.

A total of 90 Fall Armyworms were required for this experiment. The Fall Armyworms were gathered from the Municipality of La Castellana. The Bacillus thuringiensis were purchased from Bacolod City. There were 18 units of 1-liter plastic containers to house the fall armyworms. There were six treatments to be replicated three times. Each treatment had 5 Fall Armyworms (FAW). The following were the application rates of Bacillus thuringiensis: T1-Control, T2-10 grams; T3-20 grams; T4-30 grams; T5-40 grams, and T6-50 grams.

Three times application of Bacillus thuringiensis was made on the first, fourth, and 7th day by direct spraying to the sugarcane whorl using a hand sprayer. All data collected in this experiment were statistically analyzed using Analysis of Variance (ANOVA).

Materials and Equipment

A sugarcane whorls (VMC 84-524 variety) were gathered in a sugarcane farm located in Hacienda Grande, La Castellana, Negros Occidental. Its characteristic is long, not too big but sweet. The sugarcane whorls used were approximately three (3) months old. Bacillus thuringiensis (Bt) was purchased in Bacolod City, Negros Occidental. Tools such as hand spray guns, weight measurements, mixtures containers, and other devices used by the researchers were provided at their own expense.

The Fall armyworms were collected in the corn field in the Municipality of La Castellana, Negros Occidental. Fall armyworms were collected through handpicking during the daytime.

All containers were sterilized to kill microorganisms that were present in the containers. Rutala and Weber (2017), sterilization eliminates all organisms on its surface or in a fluid to avoid the

transmission of pathogens associated with the usage of an item. Containers were put into the casserole. The researchers made sure it was fully submerged in the water. Then, bring the water to a boil for five (5) minutes.

The Bacillus thuringiensis powder was measured according to the application rate as indicated on the product label. Bacillus thuringiensis powder was dissolved in water according to the treatment level by ratio and proportion. The Bacillus thuringiensis solution was placed in a spraying bottle as a biopesticide.

This study followed a Complete Random Design (CRD) with six treatments and three (3) Replications. As an experimental study, the researchers used sugarcane whorl as the experimental crop. Furthermore, the parametric data gathered included the mortality rate of Fall Armyworm following Bacillus thuringiensis treatment.

There were six (6) treatments replicated three (3) times as follows: T1 – Control, T2 – 10 grams Bacillus thuringiensis mixed in water, T3 – 20 grams Bacillus thuringiensis mixed in water, T4 – 30 grams Bacillus thuringiensis mixed in water, T5 – 40 grams Bacillus thuringiensis mixed in water, T6 – 50 grams Bacillus thuringiensis mixed in water

There were different rates of biopesticide used in controlling Fall Armyworm that attacks sugarcane whorl. The application was sprayed directly to the crop using hand spray thrice a week with an interval of Day 2 within Day 16 of the experiment.

Mortality rate - Dead FAW were counted from every treatment per replication. Each of them was counted per group. The data were gathered every day at 6 a.m from Day 2 to Day 16.

The data gathered were computed and subjected to Analysis of Variance (ANOVA) in CRD using STAR 2.0.1, and Least Significant Difference (LSD) was used to determine significant differences among treatments. Michael Darcy's Mortality Rate Calculator was used.

RESULTS, DISCUSSIONS, AND IMPLICATIONS

Table 1. Summary of means on the Percent Mortality Rate of fall armyworm under different application rates of Bacillus thuringiensis treatments from Day 2 to Day 5 of observation. T1 Control (T1 – Control13.33; 20.00; 66.67; 80.0). T2 - 10 - grams Bt (T2 – 10 grams Bt (26.67; 66.67; 93.33; 100.00). T3 – 20 grams Bt (13.33; 40.00; 46.67; 66.67). T4 – 30 grams Bt (13.33; 66.67; 80.00; 93.33). T5 – 40 grams Bt (0.50; 60.00; 80.00; 100.00). T6 – 50 grams Bt (13.33; 86.67; 86.67; 93.33). CV (%) (13.28; 13.39; 10.27; 20.54)

Results showed that applying Bt treatments does not significantly affect the percent mortality rate of fall armyworm from Day 2 to Day 5. It was noted during the first observation on Day 2 fall armyworm under 10 grams of Bt treatment (T2) obtained the highest mortality rate of 26.67 percent, which was followed by application rates of 20, 30, and 50 grams Bt treatments (T3, 4 and 6) with the same average mortality rate of 13.33 percent. Similarly, fall armyworm under control (no Bt application) got the same average mortality rate of 13.33 percent, while those under 40 grams Bt treatment (T5) had zero mortality rate.

It was noted during the first observation on Day 2 fall armyworm under 10 grams of Bt treatment (T2) obtained the highest mortality rate of 26.67 percent, which was followed by application rates of 20, 30, and 50 grams Bt treatments (T3, 4 and 6) with the same average mortality rate of 13.33 percent. Similarly, fall armyworm under control (no Bt application) got the same average mortality rate of 13.33 percent, while those under 40 grams Bt treatment (T5) had zero mortality rate.

On Day 3 of observation, fall armyworm under 60 grams Bt treatment (T6) obtained the highest mortality rate of 86.67 percent. It was followed by application rates of 10 grams and 30 grams Bt (T2 and T4), attaining an average mortality rate of 66.67 percent. Application of 40 grams Bt (T5)

got an average of 60 percent, while a 40 percent mortality rate was observed from using 20 grams Bt (T4). Nonetheless, fall armyworm without applying Bt treatment (control) got the lowest mortality rate of 20 percent.

On the fourth day of observation, the result showed no significant differences among treatments on using Bacillus thuringiensis (Bt) as biopesticides against fall armyworm. However, the use of 10 grams Bt treatment (T2) obtained the highest mortality rate of 93.33 percent, exceeding the efficacy of 60 grams Bt treatment (T6) which maintained a mortality rate of 86.67 percent. It was followed by application rates of 30 and 40 grams Bt treatments (T4 and T5), obtaining an average mortality rate of 80 percent. On the other hand, fall armyworm under control (T1) got an average of 66.67 percent, while those under 20 grams Bt treatment (T3) got the lowest average mortality rate of 46.67 percent on Day 4.

Moreover, a 100 percent mortality rate was already attained on Day 5 of observation under application rates of 10 and 40 grams Bt (T2 and T5). In comparison, application rates of 30 and 50 grams Bt obtained the same average mortality rate of 93.33 percent. Fall armyworm under control (T1) got an average mortality rate of 80 percent, while those under 20 grams Bt treatment (T3) got the lowest average mortality rate of 66.67 percent.

The summary mean of the mortality rate of fall armyworm under different application rates of Bacillus thuringiensis treatments from Day 6 to Day 12 of observation is shown in Table 2. Statistical analysis revealed no significant differences among treatments using Bacillus thuringiensis (Bt) against fall armyworm from Day 6 to Day 12 of observation.

In the previous observation, two application rates of Bt treatments (T1 and T5) had already attained a 100 percent mortality rate of fall armyworm. On the 6th day, the total fall armyworm under the application rate of 30 grams Bt (T4) was found completely dead, obtaining a 100 percent mortality rate.

Table 2. Summary of means on the Percent Mortality Rate of fall armyworm under different application rates of Bacillus thuringiensis treatments from Day 6 to Day 12 of observation. T1 – Control (86.67; 86.67; 86.67). T2 – 10 grams Bt (100.00; 100.00; 100.00). T3 – 20 grams Bt (73.33; 80.00; 100.00). T4 – 30 grams Bt (100.00; 100.00; 100.00). T5 – 40 grams Bt (100.00; 100.00; 100.00). T6 – 50 grams Bt (93.33; 93.33; 93.33). CV (%) (21.69; 16.75; 6.90)

It was also noted that fall armyworm under 50 grams of Bt treatment (T6) maintained an average mortality rate of 93.33 percent. At the same time, those under control (no Bt application) got an average of 86.67 percent. On the other hand, fall armyworm under 20 grams Bt treatment (T3) attained the lowest average 73.33 percent mortality rate.

On Day 8 of observation, the results showed no significant differences among treatments using Bacillus thuringiensis (Bt) as pesticides against fall armyworm. There were no changes noted in the percentage of the mortality rate of fall armyworm, except on Treatment 3 (20 grams Bt), which increased its share from 73.33 to 80.00 percent but remained as lowest percent mortality rate attained on Day 8 of observation.

From earlier observation, three treatments had fully reached the 100 percent mortality rate of fall armyworm. Finally, after four days of observation from Day 8, total fall armyworms under the application rate of 20 grams Bt treatment (T3) were completely dead, attaining a 100 percent mortality rate as well.

Nevertheless, fall armyworm under the application rate of 50 grams Bt treatment (T6) maintained a mortality rate of 93.33 percent over the past week of observation from Day 5 to Day 12. Likewise, fall armyworm under control (no Bt application) had no changes in its mortality rate from Day 6 to

Day 12. This was due to single or few fall armyworm larvae that probably developed resistance against Bt treatments for some days. Factors such as weather conditions, relative isolation, and continuous fall armyworm development should also be considered (Gutierrez-Moreno et al., 2020). As a result, in the Americas, fall armyworm is resistant to at least 29 insecticidal active ingredients in six mode-of-action categories (Gutierrez-Moreno et al., 2019).

Table 3. Summary of means on the Percent Mortality Rate of fall armyworm under different application rates of Bacillus thuringiensis treatments from Day 13 to Day 16 of observation. T1 – Control (86.67b; 93.33; 100.00). T2 – 10 grams Bt (100.00a; 100.00; 100.00). T3 – 20 grams Bt (100.00a; 100.00; 100.00). T4 – 30 grams Bt (100.00a; 100.00; 100.00). T5 – 40 grams Bt (100.00a; 100.00; 100.00) T6 – 50 grams Bt (100.00a;100.00; 100.00). CV (%) (4.82; 4.77; Constant Response Variable). Means in a column having the same letter are not significantly different at 5% level of probability test (LSD).

The summary means of the mortality rate of fall armyworm under different application rates of Bacillus thuringiensis treatments from Day 13 to Day 16 of observation is presented in Table 3. Results showed that fall armyworm was significantly affected by different application rates of Bt treatments on Day 13 of observance ($F = 4.00$, $P = 0.0228$).

Statistical analysis revealed that fall armyworm under the application rates of 10, 20, 30, 40, and 50 grams of Bacillus thuringiensis treatments were found dead, obtaining a mortality rate of 100 percent. The use of different application rates of Bt treatments was significantly effective by 13.33 percent over untreated fall armyworm under control (T1) which only got an average of 86.87 percent on Day 13 of observation.

On Day 15 of observation, the result showed no significant differences among treatments, by which all application rates of Bt treatments against fall armyworm had already obtained a complete mortality rate. However, fall armyworms under control (T1) increased the mortality rate from 86.67 to 93.33 percent. At Day 16 of observation, a 100 percent mortality rate of fall armyworm under control (T1) was finally attained. Factors such as weather conditions, relative isolation, and continuous fall armyworm development should also be considered (Gutierrez-Moreno et al., 2020).

The table shows that the Treatment 2 costs Php 42.00, Treatment 3 costs Php 84.00, Treatment 4 costs Php 126.00, Treatment 5 costs Php 168.00, and Treatment 6 costs Php 210.00. The total expenditure was Php 630.00. The above results showed that Treatments 2 and 4 achieved 100% mortality within five (5) days. Treatment 2 (T2), however, is less expensive than Treatment 4 (T4).

Cost-effectiveness studies have traditionally been used to "assess the relative cost of various therapies per unit of efficacy" (Saxe et al., 1983). They have addressed questions on how much money per unit. The outcome changes the treatment costs and/or how expensive one treatment modality is concerning another. Expense-benefit assessments consider the number of benefits created per dollar of program cost or investment made to create the benefits.

The incremental cost-effectiveness ratio (ICER) and the average cost-effectiveness ratio (ACER) are the two cost-effectiveness metrics used (ACER). The incremental cost per incremental benefit is a broad definition of ICER. In the medical field, ICER is an incremental ratio of the difference in total incurred cost between one approach and the next best strategy to the difference in the total number of infections avoided with each method. ACER is the cost-benefit ratio, defined as the ratio between the entire intervention cost and the natural condition avoided.

CONCLUSION AND RECOMMENDATIONS

Fall armyworm is one of the most destructive whorl feeders in sugarcane. This study evaluated the efficacy of different application rates of Bacillus thuringiensis (Bt) as pest control against fall armyworm in sugarcane whorl. Specifically, it aimed to: (1) determine the significant effects of different application rates of Bt treatments against fall armyworm; and (2) determine the most effective application rate of Bt treatment used in the study. The experiment was conducted at the School of Agriculture in the University of Negros Occidental – Recoletos, Bacolod City, in July 2021.

The study used a total of ninety (90) fall armyworms collected from the Municipality of La Castellana. Eighteen units of liter plastic containers were used to house the fall armyworms, wherein each container had five larvae. The study was laid out in Complete Randomized Design (CRD), consisting of six (6) treatments with three (3) replications. The treatments were as follows: T1 – Control; T2– 10 grams Bt; T3 – 20 grams Bt; T4 – 30 grams Bt; T5 – 40 grams Bt; and T6-50 grams Bt. Data gathered were computed and subjected to Analysis of Variance (ANOVA) in CRD using STAR 2.0.1, and Least Significant Difference (LSD) was used to determine significant differences among treatments.

Statistical analysis revealed significant differences among treatments on the mortality rate of fall armyworm as subjected to different application rates of Bt treatments, only on the 13th day of observation ($F = 4.00$, $P = 0.0228$). The result showed a complete mortality rate of fall armyworms under all application rates of Bt treatments, except only those fall armyworms under control (T1), which only got an average mortality rate of 86.67 percent, significantly inferior by 13.37 percent.

Moreover, it was found that application rates of 10 grams and 40 grams (T2 and T5) of Bt treatments early obtained a complete mortality rate of fall armyworm at Day 5 compared to other treatments. On the other hand, untreated (T1) fall armyworm attained a 100 percent mortality rate on Day 16 of observation.

From the above results, the researcher had come up with the following conclusion:

Based on the results shown in Table 3 of Mortality rate on Day 13-16, the different application rates of Bt treatments had significantly affected the fall armyworm on Day 13 of observation ($F = 4.00$, $P = 0.0228$). Therefore, null hypothesis 1, there is no significant effect in the use of Bacillus thuringiensis as a biocide to the population of the FAW in sugarcane whorl, is rejected.

Based on the results, there was no significant difference among treatments on the mortality rate of fall armyworm from Day 2 to Day 12 and Day 15. The complete mortality rate in all treatments was obtained on Day 16. Therefore, null hypothesis 2, there is no significant difference in the use of Bacillus thuringiensis as a biopesticide against FAW in sugarcane whorl, is accepted.

Based on the expenses incurred per treatment, there was the cost expense per Bt treatment in the study: treatment 2 (T2) cost Php 42.00, Treatment 3 (T3) cost Php 84.00, Treatment 4 (T4) cost Php 126.00, Treatment 5 (T5) costs Php 168.00, and Treatment 6 (T6) costs 210.00. Treatment 2 (T2) is the less expensive but more effective Bt treatment against FAW, costing only Php 42.00, which can help farmers save money. Therefore null hypothesis 3, no significant difference in the cost of expenses per Bt treatment application in the study, is rejected.

Based on the result of the data gathered and statistical analysis, the researchers recommend the following:

The use of 10 grams (T2) Bt treatments in controlling fall armyworm effectively, among other treatments. Bacillus thuringiensis (var. kurstaki) (Btk) was tested against the diamondback moth (DBM) on cabbage at Botswana College of Agriculture in Gaborone, Botswana. Bioassays were

performed at 30°C to 5°C using five doses of Btk: 2, 4, 6, 8, and 10 g/L on DBM eggs and second instar larvae. Legwaila et al. (2015) discovered that ten g/L Btk was particularly effective in controlling Diamond black moth on cabbage. They conclude that Btk can be utilized to effectively suppress DBM eggs and larvae while also reducing cabbage damage in greenhouse conditions.

The use of 10 grams (T2) Bt treatments in controlling fall armyworm efficiently. Salehi Jouzani et al. (2018) presented an incubator and batch fermenter study to optimize growing conditions and establish a low-cost bioprocess for mass production of a native coleopteran-effective Bacillus thuringiensis (Bt) strain (KH4) based on agricultural wastes. Based on their findings, the strain's growth conditions were adjusted, and a new affordable and widely available commercial fermentation medium was designed, enabling mass production of the strain in batch systems.

Together with this study, having a cost-effective biopesticide could assist farmers in reducing their expenses while controlling FAW.

The use of 10 grams (T2) has the lowest cost and results in a 100% mortality rate in five (5) days. Treatment 2 only costs Php 42.00 based on the expenses incurred per the treatment table. Treatments such as treatment 3 cost Php 84.00, treatment 4 costs Php 126.00, treatment 5 costs Php 168.00, and treatment 6 costs Php 210.00

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